

WHAT IS CLAIMED IS:

1. A transthoracic defibrillator for external defibrillation, the defibrillator comprising:

three or more electrodes configured to be attached to the thorax of a patient to establish at least two electrical paths across the thoracic cavity and through the heart of the patient;

cables to connect the three or more electrodes to a defibrillator circuit contained in a defibrillator housing;

wherein the defibrillator circuit has the capability to deliver a different defibrillation waveform across each of the at least two electrical paths.

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2. The defibrillator of claim 1 wherein the different defibrillation waveforms differ in at least one waveform parameter.

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3. The defibrillator of claim 1 wherein the defibrillator circuit has the capability to deliver the same defibrillation waveform across each of the at least two electrical, paths.

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4. The defibrillator of claim 1 wherein the defibrillator circuit includes a processing unit for determining an transthoracic impedance distribution and for selecting the waveform parameter of the at least two electrical paths based on the transthoracic impedance distribution.

5. The defibrillator of claim 4 wherein the transthoracic impedance distribution is two dimensional.

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6. The defibrillator of claim 4 wherein the transthoracic impedance distribution is determined by measuring impedances between locations on the thorax.

7. The defibrillator of claim 6 wherein measuring impedances between locations on the thorax comprises measuring impedances between the electrodes.

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8. The defibrillator of claim 4 wherein the transthoracic impedance distribution is measured using electrical impedance tomography (EIT).

5 9. The defibrillator of claim 4 wherein the transthoracic impedance distribution is measured using an imaging technique to determine positions of tissue regions, and computing the transthoracic impedance distribution from the positions of tissue regions and resistivities of the tissues.

10 10. The defibrillator of claim 9 wherein the imaging technique comprises ultrasound imaging.

15 11. The defibrillator of claim 9 wherein the imaging technique employs at least one transducer element integrated into a defibrillation pad supporting at least one of the electrodes.

12. The defibrillator of claim 4 wherein the at least one parameter of each waveform is one of tilt, duration, current, or voltage.

20 13. The defibrillator of claim 4 wherein the waveforms are biphasic.

14. The defibrillator of claim 4 wherein the waveforms are monophasic.

15. The defibrillator of claim 4 wherein the waveforms are multiphasic.

25 16. The defibrillator of claim 13 wherein the waveforms are interlaced.

17. The defibrillator of claim 14 wherein the waveforms are interlaced.

30 18. The defibrillator of claim 13 wherein the at least one parameter of each waveform is one of tilt, duration, current, voltage, first phase duration, second phase duration, first phase average current.

19. The defibrillator of claim 4 wherein the waveforms across different electrical paths are overlapping in time by at least 1 millisecond but by less than 80 percent of the duration of the shortest of the waveforms.

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20. The defibrillator of claim 4 wherein the waveforms across different electrical paths are delivered simultaneously.

10 21. The defibrillator of claim 4 wherein the waveforms across different electrical paths are delivered sequentially without overlapping in time.

22. The defibrillator of claim 4 wherein the at least one waveform parameter of each waveform is adjusted to achieve substantially the same defibrillation efficacy for each electrical path.

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23. The defibrillator of claim 4 wherein the at least one waveform parameter of each waveform is adjusted to achieve a selected current density distribution at the heart.

20 24. The defibrillator of claim 23 wherein the at least one waveform parameter of each waveform is adjusted to make the current density distribution at the heart more uniform than would be the case if the waveform parameter were the same for each of the electrical paths.

25 25. The defibrillator of claim 23 wherein the current density is either peak or average current density.

26. The defibrillator of claim 4 wherein at least two electrodes positioned on the same side of the thorax are combined into a unitary electrode pad that is adhered to and removed from the patient as one unit.

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27. The defibrillator of claim 26 wherein there are at least four electrodes, two on each side of the thorax, and two electrodes on each side of the thorax are each combined into a unitary electrode pad that is adhered to and removed from the patient as one unit.

5 28. The defibrillator of claim 4 wherein the area of each of the electrodes through which the waveforms are delivered is less than 70 percent of the projected area of the heart, and the sum of the areas of the electrodes on the same side of the thoracic cavity is greater than 80 percent of the projected area of the heart.

10 29. The defibrillator of claim 4 wherein the determination of a transthoracic impedance distribution occurs at the time of or just prior to delivery of the defibrillation waveforms.

15 30. A method of external electromagnetic stimulation of the interior of the body, the method comprising:

applying three or more electrodes to the exterior of the patient to establish at least two electrical paths across the interior of the patient;

determining impedance information representative of an impedance distribution across the interior of the body;

20 delivering an electromagnetic waveform across each of the at least two electrical paths, wherein at least one parameter of the waveform is selected using the impedance information to produce a selected current density distribution at one or more locations within the interior of the body.

25 31. The method of claim 30 wherein the electromagnetic stimulation is for defibrillation or cardioversion of the heart, the impedance distribution is across the thorax, and the current density distribution is at the heart.

30 32. The method of claim 30 or 31 wherein determining impedance information comprises electrical impedance tomography (EIT).

33. The method of claim 30 or 31 wherein determining the impedance information comprises imaging the body to determine positions of tissue regions, and computing the transthoracic impedance distribution from the positions of tissue regions and resistivities of the tissues.

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34. The method of claim 33 imaging comprises ultrasound imaging.

35. A method of performing transthoracic defibrillation, comprising:
attaching three or more electrodes to the thorax of a patient to establish a plurality of
10 electrical paths across the thoracic cavity and through the heart of the patient; and
delivering a defibrillation waveform across each of at least two of the electrical paths;
wherein the area of each of the electrodes through which the waveforms are delivered
is less than 70 percent of the projected area of the heart, and the sum of the areas of the
electrodes on the same side of the thoracic cavity is greater than 80 percent of the projected
15 area of the heart.

36. The method of claim 35 further comprising
measuring an electrical, electrocardiographic, physiological, or anatomical parameter
of the patient; and

20 delivering defibrillation waveforms that under at least some circumstances are
different for different electrical paths, with at least one parameter of each waveform being
dependent on the measured parameter.

37. The method of claim 36 wherein measuring comprises determining a
25 transthoracic impedance distribution.

38. The method of claim 35 wherein the area of each of the electrodes through which
the waveforms are delivered is less than 60 percent of the projected area of the heart.

30 39. The method of claim 35 wherein the area of each of the electrodes through which
the waveforms are delivered is less than 50 percent of the projected area of the heart.

40. The method of claim 35 wherein the sum of the areas of the electrodes on the same side of the thoracic cavity is greater than 90 percent of the projected area of the heart.

5 41. The method of claim 35 wherein the sum of the areas of the electrodes on the same side of the thoracic cavity is greater than 100 percent of the projected area of the heart.

10 42. The method of claim 35 wherein the electrodes are positioned in anterior and posterior locations, so that the electrical paths extend between the anterior and the posterior of the patient's thorax.

43. The method of claim 35 wherein the electrodes are positioned at lateral locations, so that the electrical paths extend between left and right sides of the patient's thorax.

15 44. The method of claim 35 wherein the waveforms are multiphasic.

45. The method of claim 35 wherein the waveforms are monophasic.

20 46. The method of claim 35 wherein at least two of the electrodes are combined in one unitary electrode pad that is applied and removed from a patient as a unit.

47. The method of claim 46 wherein there is a seam line between areas of the pad in which electrodes are supported, with the seam line being constructed so that the pad can be folded without creasing the areas in which electrodes are supported.

25 48. The method of claim 46 wherein there are a multiplicity of electrodes arranged on the unitary electrode pad.

30 49. The method of claim 48 wherein the multiplicity of electrodes are arranged to increase packing density.

50. The method of claim 49 wherein the electrodes are arranged in the form of a polygon tessellation.

5 51. The method of claim 50 wherein the tessellation is a regular tessellation comprising regular polyhedra symmetrically tiling a plane.

10 52. The method of claim 51 wherein the polyhedra are one of a triangle, square, or hexagon.

15 53. A method of performing transthoracic defibrillation, comprising:
attaching three or more electrodes to the thorax of a patient to establish at least two electrical paths across the thoracic cavity and through the heart of the patient;
delivering a biphasic or multiphasic defibrillation waveform across each of the at least two electrical paths,
wherein under at least some circumstances the multiphasic waveforms delivered are different for the at least two electrical paths.

20 54. The method of claim 53 further comprising
determining a transthoracic impedance distribution across the at least two electrical paths; and
delivering the biphasic or multiphasic waveforms with at least one parameter of each multiphasic waveform being dependent on the transthoracic impedance distribution.

25 55. The method of claim 53 wherein there are two pairs of electrodes, with one electrode of each pair located on generally opposite surfaces of the thorax.

56. The method of claim 54 wherein one electrode of each pair is located on the anterior and the posterior surfaces of the thorax.

30 57. The method of claim 53 further comprising a pair of bridge circuits, one bridge circuit for generating each of the biphasic or multiphasic waveforms.

58. The method of claim 53 wherein the biphasic or multiphasic waveforms are delivered so as to overlap in time.

5 59. The method of claim 58 wherein the biphasic or multiphasic waveforms are simultaneous.

60. The method of claim 53 wherein the biphasic or multiphasic waveforms are sequential.

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61. A defibrillation electrode comprising:
a first electrical wire for conveying a defibrillation pulse to or from the electrode;
a metallic layer connected to the electrical cable;
a conductive, skin-contacting layer for conveying the pulse from the metallic layer to
15 the skin;
an ultrasound sensor; and
a second electrical wire for connecting the ultrasound sensor to an ultrasound imaging circuit.

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62. A method of performing transthoracic defibrillation, comprising:
attaching three or more electrodes to the thorax of a patient to establish a plurality of electrical paths across the thoracic cavity and through the heart of the patient;
using at least two different defibrillation circuits to generate at least two generally different defibrillation waveforms;
25 delivering one of the at least two different defibrillation waveforms across each of the at least two electrical paths, and
synchronizing delivery of the at least two defibrillation waveforms by communications between the at least two different defibrillation circuits.

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63. The method of claim 62 wherein the defibrillation circuits each comprise a processor, an energy delivery circuit, and a switching circuit.

64. The method of claim 63 wherein the defibrillation circuits are contained in separate housings, and the communications occurs between the housings.

5 65. The method of claim 63 wherein the switching circuit is capable of generating a biphasic or multiphasic defibrillation waveform.

66. The method of claim 62 wherein the synchronizing delivering includes analog communication between the defibrillation circuits.

10 67. The method of claim 62 wherein the synchronizing delivering includes digital communication between the defibrillation circuits.

15 68. The method of claim 62 wherein the defibrillation circuits are contained in separate housings.

69. The method of claim 1 wherein the defibrillation waveforms deliver primarily electrical current.

20 70. The method of claim 1 wherein the defibrillation waveforms deliver primarily a magnetic field.

25 71. The method of claim 1, 35, 53 wherein there is an energy delivery circuit comprising one or more capacitors, a charging circuit for charging the one or more capacitors, and a switching circuit coupled to the one or more capacitors.

72. The method of claim 71 wherein an additional switch is provided for decoupling the capacitor from the charging circuit prior to delivery of the waveform.

30 73. The method of claim 71 wherein the switching circuit is configured as a Class D amplifier.

74. The method of claim 71 wherein the switching circuit is configured as a Class B amplifier.

5 75. The method of claim 71 wherein the switching circuit is configured as a Class AB amplifier.

76. The method of claim 1, 35, 53 further comprising delivering diaphragmatic stimulation.

10 77. The method of claim 76 wherein at least one diaphragmatic electrode is provided for delivering the diaphragmatic stimulation.

15 78. The method of claim 77 wherein at least two of the defibrillation electrodes and at least one diaphragmatic electrode are combined in one unitary electrode pad that is applied and removed from a patient as a unit.

79. The method of claim 1, 35, 53 wherein a device for delivering chest compressions is provided.

20 80. The method of claim 79 wherein the device for delivering chest compressions comprises a compression band surrounding the thorax.

25 81. The method of claim 79 wherein the device for delivering chest compressions comprises a piston-driven device.

30 82. The method of claim 1, 35, 53 wherein a physiological parameter is measured, and a prediction of defibrillation success based on analysis of the measured physiological parameter, and a coordinated delivery of defibrillation and chest compressions is provided based on the prediction.

83. The method of claim 82 wherein the coordinated delivery of defibrillation and chest compressions is manual, advisory, semi-automated, or fully automated.

84. The method of claim 82 wherein diaphragmatic stimulation for assisted breathing
5 is also provided.

85. The method of claim 82 wherein cardiac pacing is also provided.